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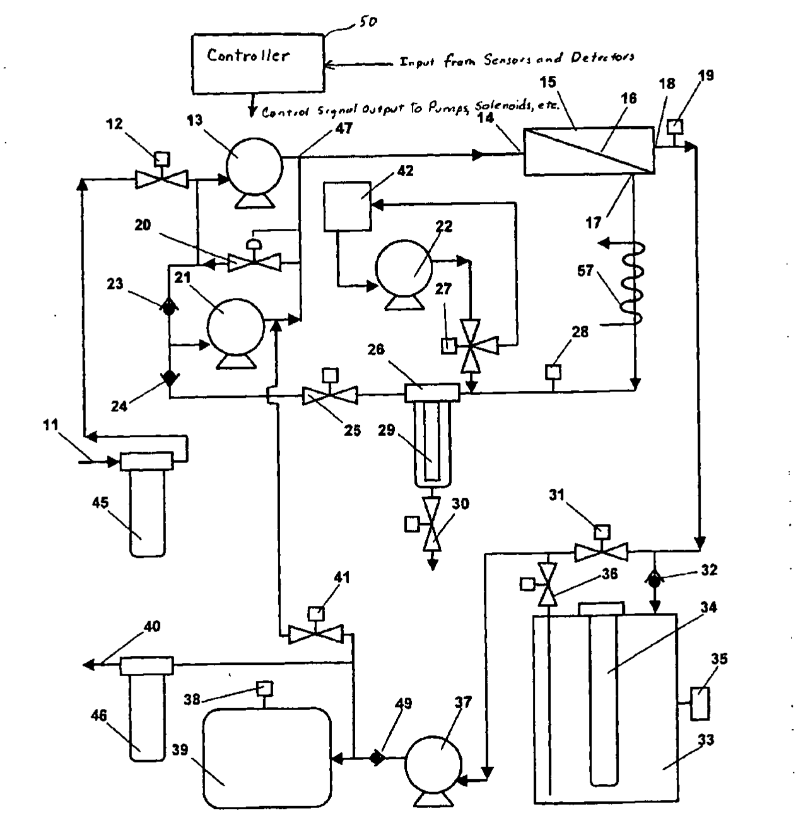

(57) Abstract: A water treatment system (10) where concentrate water from a reverse osmosis element (15) or other tangential type filter is circulated and mixed with fresh feed water in an amount that permeates a filter membrane (16). The concentration of contaminants in the circulating stream is continuously monitored and when a predetermined level is reach, the system (10) is purged of the contaminated water and a new cycle is started. This results in a water purification system (10) that will self adapt to various water conditions, at differing sites or at an installed site, to provide the most efficient use of the feed water and energy for the amount of contaminants present in the feed water at any given time.

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REVERSE OSMOSIS SYSTEM WITH CONTROLLED RECIRCULATION

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates generally to a water treatment system, and, more specifically, to a reverse osmosis system with total concentrate re-circulation, wherein the concentrate is periodically purged from the system, and wherein the system self-adjusts the period between purge cycles dependent upon the raw water quality presently being fed to the system.

Description of the Related Art

The use of reverse osmosis (RO) for treatment of water is well known and documented in numerous textbooks. Standard RO, without any recirculation of concentrate (waste) can provide high quality water but is normally inefficient in its utilization of power, feed water, and membrane life. Recirculating RO systems are more efficient in their use of feed water but are not normally without their problems. It is the systems of the recirculating type that will be further addressed.

Of the recirculating type of RO systems, there are those of the intermittent flow in open loop (Figure 1); intermittent flow in closed loop type (Figure 2); semi-continuous flow in closed loop type (Figure 3); and continuous flow type (Figure 4).

The operation of the intermittent-flow open-loop type shown in Figure 1 includes a feed tank 44 that starts full of raw water. A force-feed pump 13 pumps the feed water to the RO inlet 14 on an RO element 15. A fraction (10 to 15%) of the volume pumped by the force-feed pump 13 permeates the membrane 16, while the remainder (the concentrate) exits through a concentrate exit 17. A control valve 43 sets the pressure across the membrane sending the concentrate water back to the feed tank 44 where it mixes with the water already in the tank 44. This cycle continues until the contaminants in the water in the feed tank 44 increases to the point to where the system is no longer efficient, at which time the system is stopped, the feed tank 44 is drained and refilled with fresh raw water.

The operation of the intermittent-flow closed-loop type shown in Figure 2 begins with a feed tank 44 that starts full of fresh, raw water. A force-feed pump 13 pumps the feed water to the inlet of a recirculation pump 21, which in turn sends the water to the RO inlet 14 on an RO element 15. A fraction (10 to 15%) of the volume

pumped by recirculation pump 21 permeates the membrane 16 while the remainder (the concentrate) exits through a concentrate exit 17. The recirculation pump 21 mixes the concentrate with the feed water being pumped by force-feed pump 13 and sends a fraction of the mixed water back to feed tank 44 through control valve 43, which sets the pressure across the membrane with the remainder flowing to the RO inlet 14. This cycle continues until the contaminants in the water in the feed tank 44 increases to the point to where the system is no longer efficient, at which time the system is stopped, the feed tank is drained and refilled with fresh raw water.

The operation of the semi-continuous flow in closed-loop type illustrated in Figure 3 similarly begins with a feed tank 44 full of fresh, raw water. A force-feed pump 13 pumps the feed water to the inlet of a recirculation pump 21, which in turn sends the water to the RO inlet 14 on an RO element 15. A fraction (10 to 15%) of the volume pumped by the recirculation pump 21 permeates the membrane 16 while the remainder (the concentrate) exits through a concentrate exit 17. The recirculation pump 21 receives a fraction of the concentrate and mixes the concentrate with the feed water being pumped by the force-feed pump 13. The remaining fraction of concentrate is sent back through a control valve 43, which sets the pressure across the membrane, to the feed tank 44, which is receiving a volume of fresh water from the raw water inlet 11, equal to the volume of permeate. This cycle continues until the contaminants in the water in the feed tank 44 increases to the point to where the system is no longer efficient, at which time the system is stopped, the feed tank 44 is drained, and refilled with fresh raw water.

The operation of the continuous-flow type illustrated in Figure 4 starts with fresh raw water supplied from a raw water inlet 11 to a force-feed pump 13. The force-feed pump 13 pumps the feed water to the inlet of the recirculation pump 21, which in turn sends the water to an RO inlet 14 on an RO element 15. A fraction (10 to 15%) of the volume pumped by the recirculation pump 21 permeates the membrane 16 while the remainder (the concentrate) exits through a concentrate exit 17. The recirculation pump 21 mixes the concentrate with the feed water being pumped by the force-feed pump 13, continuously sending a fraction of the mixed water to drain through a control valve 43, which sets the pressure across the membrane, with the remainder flowing to the RO inlet 14. This cycle continues with the level of contaminants in the recirculation loop reaching a high level thus limiting the amount of water able to permeate the membrane.

There have been numerous attempts to improve the efficiency of these types of RO systems. These include the systems described in the following patents, which are summarized below.

US Patent Number 3,959,146 (Bray), while not actually of the recirculating type of RO system, attempts to increase membrane life and overall system efficiency by flushing the membrane with feed water. While this would increase the efficiency somewhat, the flushing is directly tied to the withdrawal of product water from a storage tank and not to the present condition of the system or the feed water quality.

US Patent Number 4,498,982 (Skinner) (which is of the continuous-flow type system depicted in Figure 4) recirculates a portion of the concentrate through the system during normal operation. Skinner's system is modified however, in that purified water is recirculated through the system when no water is being withdrawn. While this would aid in keeping non-purified water and its contaminants off of the membrane, the excess power requirements would quickly outweigh the benefits.

US Patent Numbers 4,626,346 (Hall) (which is of the intermittent-flow in open-loop type depicted in Figure 1), 5,282,972 (Hanna et al.), and 5,520,816 (Kuepper) (which are of the semi-continuous flow in closed-loop type as depicted in Figure 3), recirculate the concentrate (waste) stream from the RO system back to either a limited volume feed water tank, or directly to feed lines which serves to feed either the RO system or non-potable water applications such as toilets, dish washing, and bathing. While this would aid in conserving feed water in general, it provides the non-potable water applications with increasingly contaminated water. It was thought that the afore-mentioned non-potable water applications posed no threat from the use of contaminated water, however, it is now well known that many harmful affects can be caused from absorption of contaminants through the skin and through inhalation of water vapors.

US Patent Number 5,503,735 (Vinas et al) (which is of the continuous-flow type depicted in Figure 4) recirculates a portion of the concentrate stream back through the RO system. While this does utilize more of the feed water, the recirculation is only a portion of the entire concentrate stream (with the remainder going to drain) and is controlled through a pressure relief valve that is not sensitive to feed water quality. The system does have a means to flush the membrane with a combination of feed water and recirculated concentrate water. This flush is performed at predetermined intervals and is not dependent upon the condition of the system. This can result in wastage of water through premature flushing, and it can result in permanently damaged

RO elements through delayed flushing. The preferred recovery rate for the system is 50%, which means that only half of the feed water is purified while the other half is sent to drain.

US Patent Number 5,597,487 (Vogel et al.) (which is of the continuous-flow type as depicted in Figure 4) recirculates either all or part of the concentrate stream back through the RO system. While recirculating all of the concentrate through the system increases the efficiency of feed water utilization, to keep the feed water from becoming over contaminated, the system flushes after each withdrawal or on a timed basis with a mixture of purified water, feed water, and concentrate. Either way, the flushing is not performed at any optimal time with respect to the quality of the water being sent to the RO element. This can result in wastage of water through premature flushing or it can result in over-contaminated water being fed to the RO element.

US Patent Number 5,647,973 (Desaulniers) (which is of the continuous-flow type as depicted in Figure 4) attempts to improve the feed water utilization efficiency of the system through controlling the proportion of the concentrate water being recirculated based on the quality of the water being fed to the RO element. While this allows the system to adjust somewhat to varying feed water qualities, there is always a portion of the concentrate water being sent to drain, resulting in less than optimum recovery and thus waste of feed water.

US Patent Number 5,817,231 (Souza) (which is also actually of the continuous-flow type as depicted in Figure 4) purports to recirculate either all of the concentrate water or a portion thereof in an attempt to conserve feed water. However, even when it is in the mode of recirculating all of the concentrate, only that portion that remains after the concentrate pressure regulator maintains the proper backpressure on the RO element is available for recirculation with the remainder being continuously dumped, by the pressure regulator, to drain. This again results in less than optimum recovery and thus waste of feed water.

One feature the above systems have in common is that the pressure differential across the membrane is established by a control valve that is controlling the continuous flow of concentrate from the pressurized area of the system to either an atmospheric tank or drain which can not utilize the energy stored in the fluid. Thus the pumps must continuously make up the energy lost through the membrane to the permeate water as well as the reject fraction lost to drain or tanks. Also, as the feed water quality varies, either by nature of the raw water fed to the system or the increase in concentrate in the recirculating loop, the osmotic pressure required to be overcome varies. The control valve that is regulating the flow, or that is acting as no more than an

orifice, cannot fully adjust automatically for these changes, thus resulting in less than optimum efficiencies in both power and water consumption. Addition of automatic control valves to accomplish the changes required for various water qualities is prohibitively expensive, complicated, and subject to failure especially when the application is for a system to provide safe drinking water to an entire house.

BRIEF SUMMARY OF THE INVENTION

The disclosed embodiments of the invention provide a water treatment system that utilizes reverse osmosis where the contaminants are physically removed from the product water stream rather than converting them to some other form through oxidation, chemical addition, or ion exchange. Preferably, the system provides total concentrate re-circulation with the concentrate periodically purged from the system, and the purge is initiated by automatic control using electrical or mechanical monitoring of the concentrate concentration to initiate the purge cycle. In one embodiment, the system self adjusts the period between purge cycles dependent upon the raw water quality presently being fed to the system, thus making the system suitable for universal distribution without being specifically tailored for the water quality at the installed site. This water treatment system is suitable for industrial, commercial, and medical applications as well as residential, particularly to a "Whole House" or "Point Of Entry" type system for residential applications where the treated water is supplied to all water outlets within or outside the living quarters.

In accordance with one embodiment of the invention, a water treatment system is provided that includes a filtration branch to receive raw water, filter the raw water via a filter, and output permeate (filtered water) and concentrate (waste); a recirculation branch to receive and recirculate the concentrate to the filtration branch; and a permeate storage and exit branch to receive and store the permeate, and to exit the permeate from the system and return the permeate to the filtration branch; and the filtration branch and the recirculation branch configured to purge the filter when the concentrate reaches a predetermined contaminant level.

In accordance with another embodiment of the invention, a water purification system is provided that includes a tangential filtration component with a filter membrane; a component to circulate concentrate water; a component to add fresh feed water to the circulating concentrate water so as to replace the amount of water permeating the tangential filtration membrane; a component to determine when the contaminant level of the circulating water reaches a predetermined level; a component to purge the system of contaminated water once the predetermined level is reached; and

a component to replenish the system with fresh feed water as the system is purged of contaminated water.

As will be readily appreciated form the foregoing, the disclosed embodiments of the invention satisfy the need for a fully functioning system capable of providing safe drinking water quality water, with an average of 98% of the contaminants physically removed, to an entire house or to other systems that could benefit from a cost effective, resource conservative, energy efficient source of high purity water. The system will function without modification or human intervention over a broad range of feed water qualities, has the ability to self adjust the recovery percentage of the feed water so as to maintain the maximum utilization of the feed water based upon the feed water quality, has the ability to maintain a high level of contaminant rejection without compromising product water quality, has the ability to produce high quality water with high recovery rates while keeping energy usage to a minimum, has the ability to preserve the integrity and performance of the RO elements and their membranes, has the ability to perform all of the above while keeping component count and complexity to a minimum and while providing a high degree of reliability.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The foregoing and other features and advantages of the present invention will be more readily appreciated as the same become better understood from the following detailed description when taken in conjunction with the accompanying drawings wherein like numbers refer to like elements and wherein:

Figure 1 is a diagram illustrating the prior art of an intermittent flow in an open-loop type RO system;

Figure 2 is a diagram illustrating the prior art of an intermittent flow in a closed-loop type RO system;

Figure 3 is a diagram illustrating the prior art of a semi-continuous flow in a closed-loop type RO system;

Figure 4 is a diagram illustrating the prior art of a continuous-flow type RO system;

Figure 5 is a diagram illustrating one embodiment of the invention; and

Figure 6 is a graph showing the volume of water produced between purges for a range of feed water conditions.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 5, shown therein an embodiment of a water filtration system 10 that is suitable for use as a "whole house" or "point of entry" water treatment system and that is intended to supply an entire dwelling (sinks, tub, toilets, clothes washer, dishwasher, icemaker, and all other potable as well as non-potable water sources) with drinking water quality water.

The system 10 includes a raw water inlet 11 providing raw water to a filtration branch that includes the inlet of a raw water carbon filter 45, which outputs filtered raw water to an inlet solenoid valve 12. The output of the solenoid valve 12 is coupled to the input of a force-feed pump 13 and to a raw water check valve 23.

In the filtration branch the force-feed pump 13 pumps the filtered raw water to an RO inlet 14 on a RO element 15 that includes a tangential RO membrane 16. The function of the tangential RO membrane 16 is well–known to those skilled in the art and will not be described in detail herein. A permeate conductivity level detector 19 is positioned at an RO permeate exit 18 of the RO element 15 where filtered permeate water or product water passes from the RO element 15. A concentrate exit port 17 on the RO element 15 conducts the concentrate to a recirculation branch that includes a concentrate conductivity level detector 28, a recirculation filter 26 downstream therefrom, which includes a filter element 29 and purge dump solenoid valve 30, and thence to a recirculation solenoid valve 25 and a series-connected recirculation water check valve that opens to an input of a recirculation pump 21. The raw water check valve 23 also opens to the recirculation pump 21.

Coupled to the recirculation branch is a process aid branch that includes a three-way process aid feed solenoid valve 27 coupled to the input of the recirculation filter 26 and having one output coupled to a process aid feed reservoir 42 that empties to a process aid feed pump 22, which in turn supplies pumped process aid fluid to a second input on the process aid feed solenoid valve 27.

The filtration branch is coupled to a permeate storage and exit branch via the RO permeate exit 18, which connects to a permeate check valve 32 that opens to a product water reservoir 33 having a UV light 34 therein. The RO permeate exit 18 also connects to a permeate steering solenoid valve 31 that outputs to the intersection of a reservoir outlet solenoid 36, which is coupled to the product water reservoir 33 and to a line leading to a product water pressure pump 37, which supplies pumped permeate water to a product water pressure tank 39 and to a product water purge solenoid valve 41 that outputs to a tee connection 47 at the output of the force-feed pump 13 via the

output of the recirculation pump 21. The product water pressure pump 37 also outputs to a product water carbon filter 46 that in turn outputs to a product water exit 40.

As an option, a heat exchanger 48 can be utilized to increase the temperature of the concentrate water, which in turn increases the temperature of the water entering the RO element 15. Most RO elements provide higher throughput on warmer water, thus heat exchanger 48, by inputting heat energy into the feed fluid to the RO elements, causes an increase in performance. Furthermore, the heat energy input into heat exchanger 48 can either be from a primary source or from waste heat from wastewater, air conditioning exhaust, ground source, or air source.

During a purification cycle, feed water, which may be sourced from a municipal water system, well, spring, or other suitable source for potable water, enters the system through the feed water inlet 11, and goes directly into the system's pre-filtration subsystem 45, which in the case of this particular embodiment consists of simply a carbon block filter. However it may consist of a particulate filter, granular activated carbon filter or other combinations of commercially available filtration devices suited for the contaminants normally found in the source water and which will provide the necessary protection from oxidants and other harmful chemicals for the reverse osmosis elements 15, as well as lower peak concentrations of chemicals that may not be satisfactorily removed through the RO process.

Next, the pretreated feed water flows through the inlet solenoid valve 12, which closes to stop the flow of feed water into the system and opens to allow water to flow. During normal operation, the feed water is picked up by the force-feed pump 13, which is preferably of the positive displacement type and which pumps a volume of feed water equal to the volume of product water expected at the RO permeate exit 18. From the force-feed pump 13, the feed water then flows to the RO inlet 14, where within the RO element 15, the feed water is exposed to the RO membrane 16. The pressure regulating valve 20 ensures damaging pressures are not generated, sending excess water back to the inlet of the force-feed pump 13. Because all lines are full during normal operation, and there is no exit from the filtration branch or purification loop, the operation of which will be described in detail later, the force-feed pump 13 injects the feed water under pressure substantial enough, yet within the limits of the system established by valve 20, to cause its entire volume to flow through the RO membrane 16 and out the RO permeate exit 18.

Simultaneously, during normal operation, the recirculation branch, which basically consists of the RO concentrate exit 17, the concentrate conductivity level detector 28, the recirculation filter 26, the recirculation water solenoid valve 25,

the recirculation the water check valve 24, the recirculation pump 21, the water combination tee 47, is full of water at all times, which flows back to the RO element 15 through the RO inlet 14. The recirculation branch is flowing, for the most part, at a rate established by the pump 21, which is preferably of the centrifugal type and pumps at a flow that is close to the maximum allowed through the RO element 15, less the flow produced by force-feed pump 13. The primary function of the high flow produced by the pump 21 is to keep the concentration of contaminants at the surface of the feed water side of RO membrane 16, swept clear of the immediate membrane surface. This allows the reverse osmosis process to function at closer to the actual concentration of contaminants in the water rather than at an elevated concentration due to a higher concentration of the contaminants on the surface of the membrane where the actual work is being accomplished.

As the system is operating, approximately 20% of the total flow of water into the RO element 15, less approximately 98% of the contaminants, permeate the RO membrane 16, and exits through the RO permeate exit 18 as purified water. The remaining 80% of the flow, along with the contaminants not passing through the membrane, exits through the RO concentrate exit 17.

For illustrative purposes, the following example assumes an initial feed water concentration equivalent to 1,000 ppm and a recirculation flow of 37.85 liters (10 gallons) per minute. As the water flows the first time through the RO element 15, 20% of the flow, or 7.57 liters (2 gallons) per minute, is forced to permeate the RO membrane 16, while 30.28 liters (8 gallons) per minute flows out through the RO concentrate exit 17. This water is now at a concentration of 1245 ppm as can be seen by equation 1,

$$C_c = (F_c - (F_c \cdot P_r \cdot R_p))/(1-P_r) \qquad (1)$$

Where F_c = Fresh Water Feed Concentration in ppm

P_r = Percent Recovery Fraction

R_p = Permeate Percentage Fraction of Contaminants

Cc = Concentrate Concentration in ppm

$$Cc = (1000 - (1000 \cdot 0.2 \cdot 0.02))/(1-0.2)$$

$$Cc = (1000 - 4)/0.8$$

$$Cc = 966/0.8$$

$$Cc = 1245 \text{ ppm}$$

while the concentration of contaminants in the permeate water is roughly 2% of the concentration fed to the RO element 15, or 20 ppm. As the concentrate water mixes, at

the tee 47, with fresh feed water at the rate of 7.57 liters (2 gallons) per minute, the concentration in recirculating feed water now becomes 1196 ppm as can be seen by equation 2.

$$F_{rc} = (C_c \cdot (1 - P_r)) + (F_c \cdot P_r) \qquad (2)$$

Where F_c = Fresh Water Feed Concentration in ppm

F_{rc} = Recirculating Feed Water Concentration in ppm

P_r = Percent Recovery Fraction

Pf = Permeate Flow

Cc = Concentrate Concentration in ppm

$Frc = (1245 \cdot (1-0.2)) + (1000 \cdot 0.2)$

$Frc = (1245 \cdot 0.8) + (200)$

$Frc = (996) + (200)$

$Frc = 1196$ ppm

As the newly mixed recirculating feed water is presented to the RO element 15, F_{rc} replaces F_c in equation 1 to form equation 3

$$C_c = (F_{rc} - (Frc \cdot Pr \cdot Rp))/(1 - Pr) \qquad (3)$$

$Cc = (1196 - (1196 \cdot 0.2 \cdot 0.02))/(1-0.2)$

$Cc = (1196 - 4.784)/0.8$

$Cc = 1191.2/0.8$

$Cc = 1489$ ppm

This water again mixes with fresh feed water and after again applying equation 2, this time using the new C_c, the new concentration in recirculating feed water now becomes 1391 ppm. This loop continues until a predetermined concentration is reached as will be described in detail later.

While the concentrate water is being recycled through the recycling loop, it passes through the recirculation filter 26, and subsequently through the recirculation filter element 29, which for this embodiment is a 2-micron string wound element. This filter has several functions. The first is to collect particles of debris, scale, or other contaminants that are large enough to become trapped in it. The second is to serve as a support for a filtration aid, which increases the ability of the filter to collect particles smaller than normally possible. The third is to provide an absorptive system that will slow release an antiscalant, which aids in keeping the RO element 15, free from scale. The forth is to provide a surface that can be flushed clean of trapped contaminants through the purge dump solenoid valve 30. The filtration aids and

antiscalants are stored in the process aid feed reservoir 42, and are delivered through the process aid feed pump 22, and the three way process aid feed solenoid valve 27.

During the normal processing mode, the three way valve 27, is ported to recirculate the process aid back to the reservoir 42 so as to ensure consistent mixing; the recirculation water solenoid valve 25, is open; the purge dump solenoid valve 30, is closed; the recirculation water check valve 24 opens and raw water check valve 23 closes due to the flow of recirculation water to the inlet of pump 21; the product water purge solenoid valve 41 is closed, in effect creating a closed loop with force-feed pump 13, making up only that portion of the recirculating water that permeates the RO membrane 16; and the concentrate conductivity level detector 28 is continuously monitoring the concentration of contaminants in the recirculation loop.

When the concentration of contaminants reaches a predetermined level (which for the purposes of this example assume a predetermined level of 2,500 ppm) the system goes into a purge mode where simultaneously the recirculation valve 25 closes, the check valve 24 closes, the raw water check valve 23 opens, and the purge dump solenoid valve 30 opens. Fresh raw water is now pumped by the pump 21 at high velocity through the RO element 15, out the RO concentrate exit 17, into the filter housing 26, and out through the purge dump solenoid valve 30 to drain. This effectively dislodges trapped contaminants along with spent filtration aid and purges them from the system. Note that there is no flow through the filter element 29 while in the purge mode. The system stays in the purge mode for either a predetermined length of time that would normally be equivalent to the length of time to purge the system of previously recirculated water or until a predetermined level of conductivity is detected by the concentrate conductivity level detector 28.

When exiting the purge mode, the purge dump solenoid valve 30 closes; the recirculation solenoid valve 25 opens; the recirculation check valve 24 opens; and the raw water check valve 23 closes establishing the normal recirculation loop. Simultaneously, with the reestablishment of the normal recirculation loop, the three way valve 27 ports, for a predetermined period of time, to allow the flow of process aid into the filter element 29. This flow of process aid is during the time that the recirculation loop pressure is low enough to allow such a flow and is for a time sufficient to allow proper dosing of the system. The system continues to alternate between the process mode and the purge mode as long as the product storage reservoir 33 is in need of water.

While, for discussion, 1000 ppm was used as the contaminant level in the raw feed water, the actual level of contaminants in feed water will vary from site to

site and may even vary to a great extent at any one particular site. Rather than have the system preset for a nominal contaminant level and have the system function at less than optimum performance, and rather than have the systems fine tuned for each installed site, the system has the inherent ability to adapt to the level of contaminants in the feed water at any given time or place. Using equations 1, 2, and 3 as the bases for a table, a graph, as depicted in Figure 6, can be constructed, which shows the volume of water produced between purges for a range of feed water conditions.

As purified water flows from the RO permeate exit 18, it passes through permeate conductivity level detector 19, which constantly monitors the conductivity of the purified water before it continues on to reservoir 33. If the purified water exceeds a predetermined conductivity, either an alarm is sounded or the system can be shut down. Under normal conditions, the purified water continues on through the permeate check valve 32 and enters the reservoir 33, where purified water is stored until needed to feed the product water pressure pump 37, in which case, the water exits the reservoir 33 through the storage reservoir outlet solenoid valve 36. While the water is stored in the reservoir 33, it is subject to airborne biological contaminants. To ensure that the microbial contaminants do not propagate, the stored water is either continuously or intermittently irradiated with UV light from the storage reservoir UV light 34.

As the level in the reservoir 33 drops, the storage reservoir level detector 35 senses the level, and at a predetermined low level it initiates a purification cycle. If, during a purification cycle, the reservoir 33 drops to a low low level (essentially out of water or at a very low level that is determined at the time the system is configured), as detected by detector 35, the permeate steering solenoid valve 31 opens, the reservoir outlet solenoid valve 36 closes, the permeate check valve 32 closes, and the purified water bypasses the reservoir 33 and is fed directly into the product water pressure pump 37. This aids the system by increasing the production rate through application of the negative pressure generated by the pump 37 directly to the low pressure, or permeate, side of the membrane 16, thus increasing the apparent pressure on the high pressure, or feed water, side of the membrane 16. This also ensures that the pump 37 will always have access to water and will not be ingesting air, which would be the case if the reservoir 33 were pumped dry.

When the product water pressure pump 37 shuts down, the water pressure from the permeate water output from the RO element 15 overcomes the permeate check valve 32, which enables water to enter the reservoir 33. As the water level in the reservoir 33 raises above the low low level, the permeate steering solenoid

valve 31 closes, and the reservoir inlet solenoid valve 36 opens, returning the flow of water to the normal configuration.

When a high level is detected in the reservoir 33 by the detector 35, the purification cycle is halted by removing power from the pump 13, the pump 21, and the pump 22. The inlet solenoid valve 12 closes, as does the recirculation valve 25. The product water purge solenoid valve 41 and the purge dump solenoid valve 30 open for a predetermined length of time, which is sufficient in length to allow purging of all contaminated water with purified water from the product water pressure tank 39 and through valve 41, from the outlet of pumps 13 and 21 through the feed water side of RO element 15, through the housing of filter 26, and out through valve 30.

As water is used, it flows out of the tank 39, into which the pump 37 has pumped purified water under pressure, through the product water carbon filter 46, and out of the product water exit 40. The product water pressure detector 38 monitors the pressure in the tank 39, and at low pressure it turns the pump 37 on and at high pressure it turns the pump 37 off. A typical low pressure is 30 PSIG, and a typical high pressure is 45 PSIG.

As the pump 37 draws water from the reservoir 33 to fill and pressurize the tank 39, the water level in the reservoir 33 drops. As this level drops below the low level established by the detector 35, a new purification cycle is started.

The same scheme outlined above with the modification of utilizing purified water to accomplish the purging of concentrated recirculation water will allow the invention to be utilized with waters of higher initial contamination levels. Using the modified scheme, brackish and seawater can both be utilized as sources of feed water for the system.

Control of the various pumps, valves, heating element, and UV light is performed by a control circuit 50 coupled to the respective components. A description of the control circuit is not provided herein, and it is within the ordinary skill of one in the art to provide a suitable control circuit that will result in system performance in accordance with the foregoing description.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims and the equivalents thereof.

CLAIMS

What is claimed is:

1. A water purification system, comprising:
tangential filtration means;
means to circulate concentrate water;
means to add fresh feed water to the circulating concentrate water so as to replace the amount of water permeating the tangential filtration membrane;
means to determine when the contaminant level of the circulating water reaches a predetermined level;
means to purge the system of contaminated water once the predetermined level is reached; and
means of replenishing the system with fresh feed water as the system is purged of contaminated water.

2. The water purification system of claim 1 wherein said concentrate water circulating means comprises:
circulating water filtration means;
means to flush out of the system, contaminants trapped by said filtration means; and
means whereby the flush of contaminants trapped by said filtration means is accomplished in conjunction with the purge of contaminated water from the circulation means.

3. The water purification system of claim 1 wherein said system further comprises:
means to add a chemical enhancer for said tangential filtration means.

4. The water purification system of claim 3 wherein said system further comprises:
means to circulate said chemical enhancer for said tangential filtration means.

5. The water purification system of claim 2 wherein said system further comprises:
means to add a chemical enhancer for said circulating water filtration means.

6. The water purification system of claim 5 wherein said system further comprises:

means to circulate said chemical enhancer for said circulating water filtration means.

7. The water purification system of claim 1 wherein said system further comprises:

means to adapt to differing water quality conditions at differing sites

8. The water purification system of claim 1 wherein said system further comprises:

means to adapt to differing water quality conditions at the installed site.

9. The water purification system of claim 1 wherein said system further comprises:

means to remove predetermined contaminants that the tangential filtration means will not remove, prior to the water entering the tangential filtration means.

10. The water purification system of claim 1 wherein said system further comprises:

means to remove contaminants that are harmful to the tangential filtration means, prior to the water entering the tangential filtration means.

11. The water purification system of claim 1 wherein said system further comprises:

means to remove contaminants that remain in the purified water after purification by the tangential filtration means and before exiting the system.

12. The water purification system of claim 1 wherein said system further comprises:

means to preheat the feed water.

13. The water purification system of claim 12 wherein said system further comprises:

means to regeneratively exchange heat from previously heated processed water; and

means to regeneratively exchange heat from previously heated waste water.

14. The water purification system of claim 1 wherein said system further comprises:

means to purge contaminated water from the tangential filtration means after completion of a purification cycle.

15. The water purification system of claim 1 wherein said system further comprises:

means to purge contaminated water from the tangential filtration means using purified water after completion of a purification cycle.

16. The water purification system of claim 1 wherein said system further comprises:

means to store purified water.

17. The water purification system of claim 16 wherein said system further comprises:

means to monitor levels in the storage means; and

means to start and stop purifications cycles based on levels in storage means.

18. The water purification system of claim 17 wherein said system further comprises:

means to pressurize water for delivery.

19. The water purification system of claim 16 wherein said system further comprises:

means to irradiate with UV light the purified water stored in the storage reservoir.

20. The water purification system of claim 1 wherein said system further comprises:

means to monitor the quality of the product water.

21. The water purification system of claim 20 wherein said system further comprises:

means to prevent contamination of stored product water when the product water monitoring means detects contaminated water.

22. A water treatment system, comprising:

a water filtration branch to receive raw water, to filter the raw water via a filter, and to output permeate and concentrate;

a recirculation branch to receive and recirculate the concentrate to the filtration branch and to detect contaminant level in the recirculation branch; and

a permeate storage and exit branch to receive and store the permeate, to exit the permeate from the system, and to return the permeate to the filtration branch, the filtration branch and the recirculation branch configured to purge the filter when the concentrate reaches a predetermined contaminant level in the recirculation branch.

23. A water treatment system, comprising:

a water filtration branch to receive raw water, to filter the raw water via a filter, and to output permeate and concentrate;

a recirculation branch to receive and recirculate the concentrate to the filtration branch and to detect contaminant level in the recirculation branch;

a process aid branch to mix process aid with the concentrate in the recirculation branch; and

a permeate storage and exit branch to receive and store the permeate, to exit the permeate from the system, and to return the permeate to the filtration branch, the filtration branch and the recirculation branch configured to purge the filter when the concentrate reaches a predetermined contaminant level in the recirculation branch.

24. A water treatment system, comprising:

a water filtration branch to receive raw water, to filter the raw water via a filter, and to output permeate and concentrate;

a recirculation branch to receive and recirculate the concentrate to the filtration branch and to detect contaminant level in the recirculation branch;

a permeate storage and exit branch to receive and store the permeate, to exit the permeate from the system, and to return the permeate to the filtration branch; and

a control circuit coupled to at least the filtration branch and the recirculation branch, the control circuit configured to control the filtration branch and the recirculation branch to purge the filter when the concentrate reaches a predetermined contaminant level in the recirculation branch.

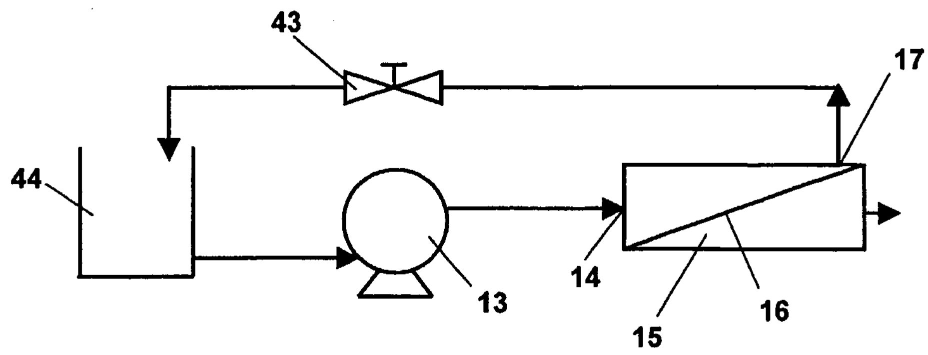

Figure 1

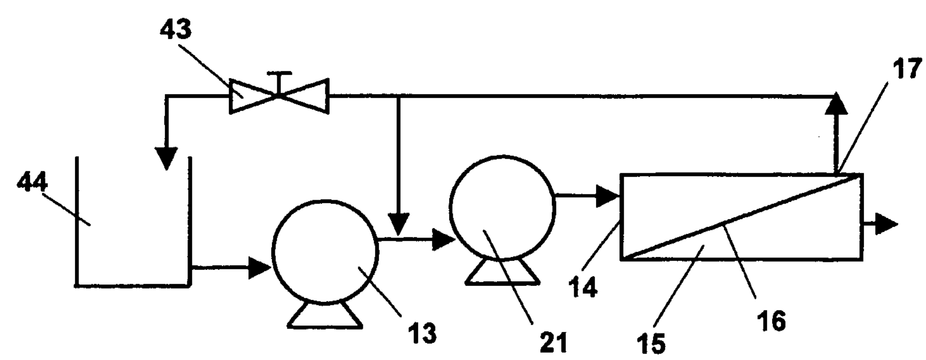

Figure 2

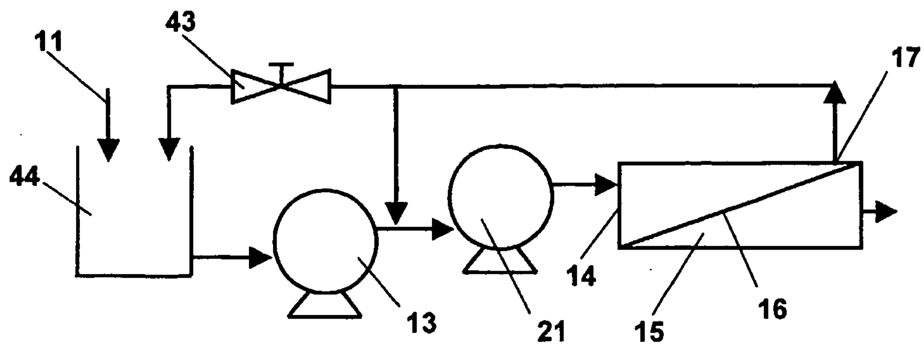

Figure 3

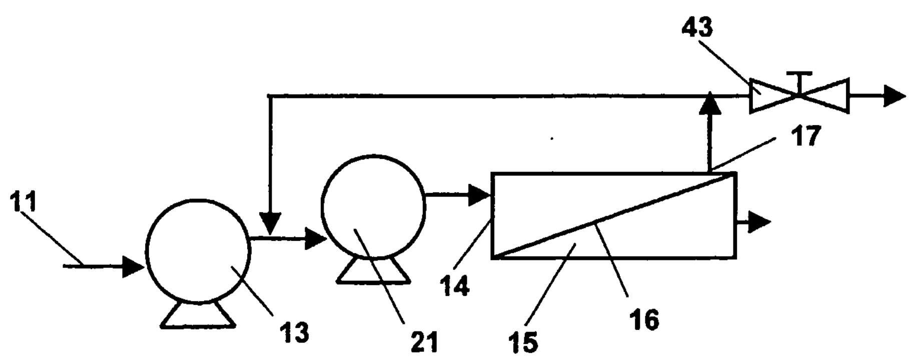

Figure 4

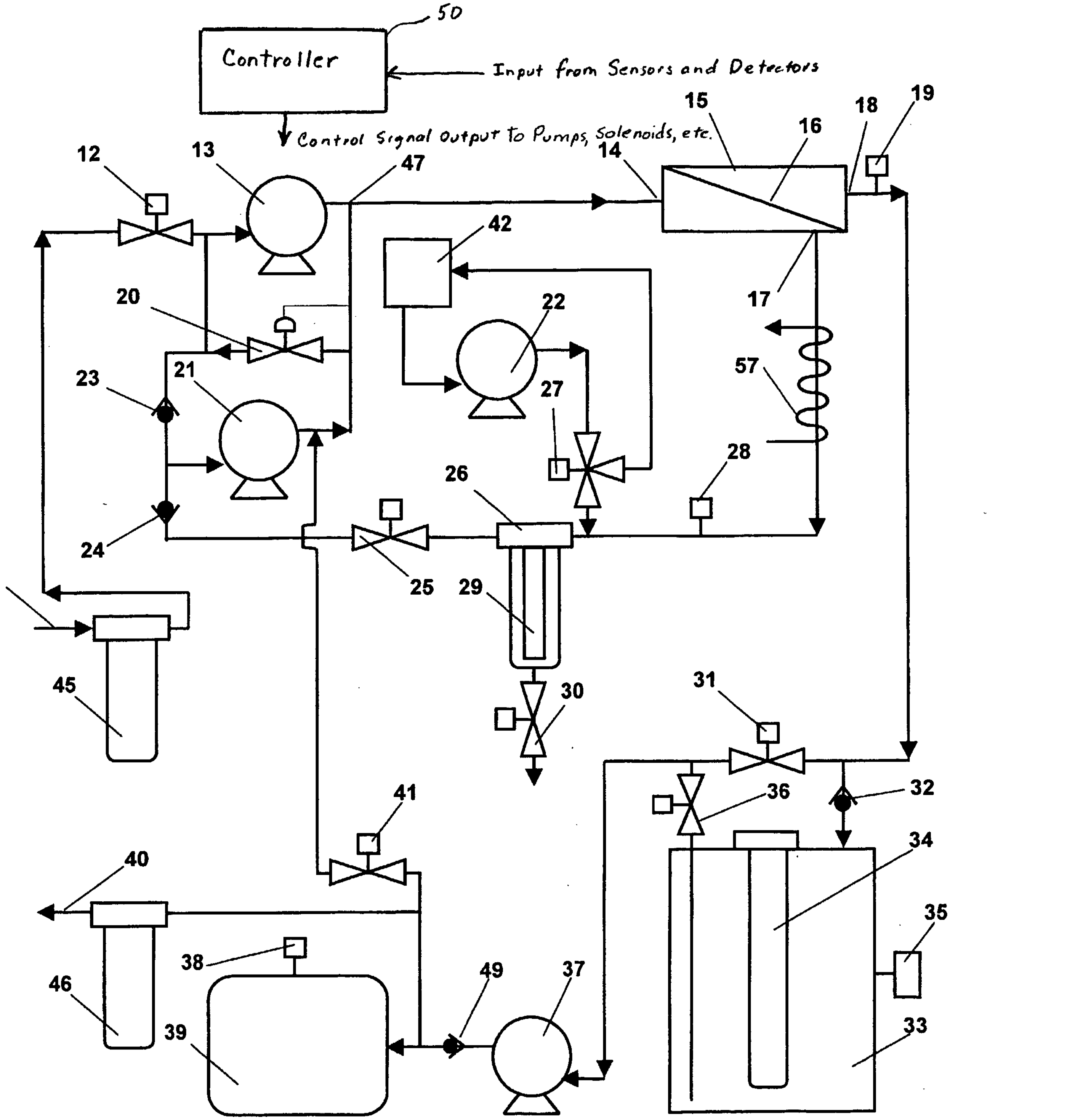
50
Controller
Input from Sensors and Detectors
Control Signal Output to Pumps, Solenoids, etc.
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Figure 5

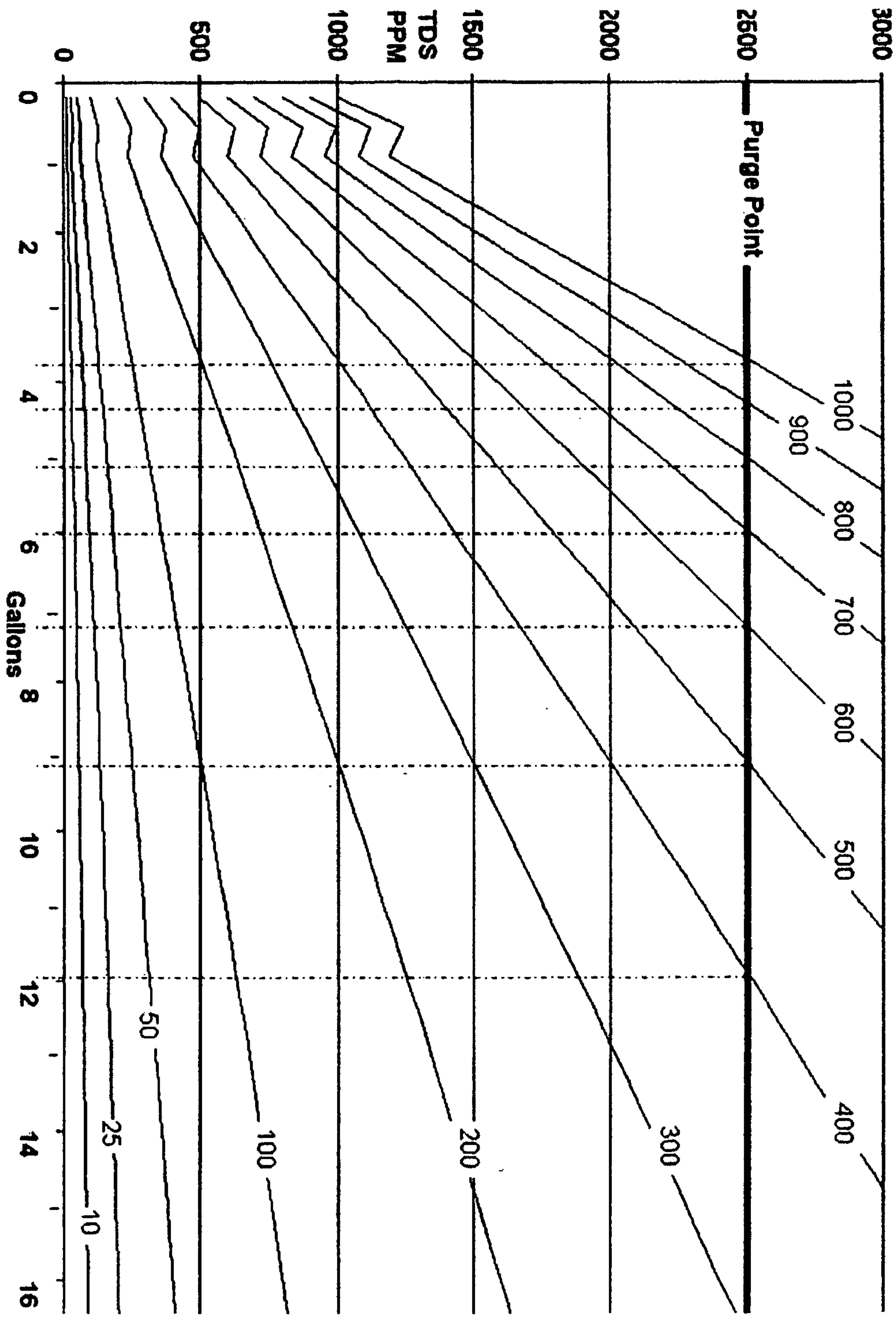
3000
2500
2000
1500
TDS
PPM
1000
500
0
Purge Point
1000
900
800
700
600
500
400
300
200
100
50
25
10
0
2
4
6
8
10
12
14
16
Gallons

Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/01023

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B01D 61/00
US CL : 210/96.2, 195.2, 257.2, 181, 202

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 210/652, 746, 85, 86, 96.2, 195.2, 257.2, 181, 202, 97, 106, 175, 196, 205, 192, 748, 257.1, 321.6, 321.65, 321.69

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,756,408 A (SPATZ et al.) 04 September 1973 (04.09.1973), whole document.	1-10, 14, 29, and 22-24
Y	US 3,708,069 A (CLARK) 02 January 1973 (02.01.1973), column 8, lines 16-29.	12-13
Y	US 6,074,551 A (JONES et al.) 13 June 2000 (13.06.2000), figure 1, column 4, lines 45-59 and column 6.	1, 11, and 14-24

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 29 April 2002 (29.04.2002)	Date of mailing of the international search report 29 MAY 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Terry K. Cecil DEBORAH THOMAS PARALEGAL SPECIALIST Telephone No. (703) 308-0661

Form PCT/ISA/210 (second sheet) (July 1998)

Continuation of B. FIELDS SEARCHED Item 3:
EAST
search terms: concentrate retentate recycle recirculation conductivity concentration